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Use of vegetated wetland to remove nitrogen from domestic sewage through ammonia volatilization

S. K. Billore and P. Dass

School of Studies in Botany, Vikram University, Ujjain 456 010, India

Direct disposal of raw municipal sewage for crop irrigation without any prior treatment revealed evidence of its rich ammonium-nitrogen content. The present study revealed significantly higher (× 2.8 times) nitrogen loss through ammonia volatilization in the vegetated wetland (flux, 113 mg ammonia/m² surface/day) because of higher flood water ammonium-N concentration compared to the wetland area without any macrophytes (flux, 40 mg ammonia/m² surface/day). The amount of ammonia loss and nitrate-N status in sewage irrigated soil without any crop was 1.5 times higher (flux, 89) than the soil with the crop (flux 57). Absence of rhizospheric factor and nitrate-N uptake enhanced both the processes at the former site. The overall study pointed that vegetated aquatic system provides a better treatment avenue for nitrogen removal.

LAND application of sewage is desirable because it decreases the hazard of environmental pollution and related health problems[1-3], creates an alternative water source since the effluent is suitable for irrigation[4] and increases economic benefits due to its high nutrient content which minimize the need for fertilization. It is essential to remove excess nitrogen from sewage before it is discharged to water bodies, as it can cause eutrophication and increase the cost of potable water treatment. Ammonia volatilization has received considerable attention in recent years because it is a major route of nitrogen loss from the plant–soil–water environment. The present investigation was undertaken to evaluate the extent of ammonia loss in: (i) wetland body containing sewage for land disposal, and (ii) sewage irrigated agricultural field, in order to find out an effective way by which the excess nitrogen of the sewage can be reduced before the reuse of the effluent.

Ammonia loss measurements *in situ* were done during Summer 1991 (May, mean min. temp. 29°C and mean max. temp. 41°C) at the Sewage Farm of Ujjain city (23°N, 74°E). The Farm covers a land area of about 2000 ha and receives untreated municipal wastewater for crop irrigation by intensive network of open and a few closed drains. Within the Farm, ammonia loss measurements were made in a shallow earthen wetland (size 2 ha, depth 120 cm) aquatic ecosystem. At times when the sewage irrigation is not required in the rest of the farm, municipal wastewater is stored into this wetland for supplemental irrigation of crops. It is a perennial aquatic body and has three major zones: (i) a dense green mantle of the free floating plant, *Lemna minor* (Duckweed) in 2/3rd area, (ii) *Typha angustifolia* (Cattail) completely covering the peripheral margins of the pond, the roots of which are as deep as one metre, and (iii) pond water surface without any macrophyte.

In this aquatic system, ammonia volatilization was measured in static acid traps, where ammonia volatilized was trapped in dilute boric acid (0.33 N). The traps consisted of 30 cm lengths of PVC pipe (i.d. = 15 cm). The lower end was inserted into water/soil and the upper end was closed by a 5 cm piece of PVC (i.d. = 16 cm) which contained two layers of fine nylon mesh (size 100 μm). Between these two layers, a glass-wool pad of 3 cm thickness (weighing 40 g) was sandwiched, soaked with 250 ml of 0.33 N boric acid and sealed by thermocole disc (5 cm thickness) to make the whole fabrication air-tight. The upper end of ammonia-absorbing unit was easily replaceable by the fresh ones for subsequent measurements. The traps were floated in the water by a tight-fitted thermocole at the base. Ammonia loss was monitored everyday for five days at two sites in three replicates: (i) free-floating *Lemna* species (15 cm water column), (ii) 'root bed' zone of *Typha* covered marginal area (15 cm water column depth for the set). Ammonia trapped in the pads was quantitatively extracted in the laboratory by fresh washings by boric acid and simultaneously squeezing to a total 250 ml extractant (since some amount of boric acid was lost between the set installation and set-dismantling for the record of observations). Ammonia concentration was measured by Orion ion analyser in a 50 ml aliquot using an ammonium electrode. Each day, the measurement sets were moved to a new site in the vicinity of the same area supporting the *Lemma/Typha* plants of almost identical age. Thus in total 15 sites were measured with 3 replicates each day during the five-days period.

In the terrestrial system ammonia loss was measured by placing the acid traps on surface of the sewage-irrigated soil at two sites – (i) soil supporting a crop (one-month-old bottle gourd, *Lagenaria vulgaris*), and (ii) sewage irrigated bare soil. The ammonia trapping and measurement method was the same as described above.

Table 1. Nitrogen characteristics of sewage before application to soil, sewage pond, and of sewage applied soil

Habitat	Total-N*	Ammonium-N*	Nitrate-N*
Sewage before soil application (mg/l)			
	100 0	52 0	1 8
Sewage pond water (mg/l)			
With vegetation (*Typha* and *Lemna*)	16 4	10 6	0 4
Without vegetation	5 7	3 5	0 1
Sewage irrigated soil (mg N/100 g oven dry soil)**			
With vegetation (*L vulgaris*)	194 0	5 8	16 1
Without vegetation	157 0	7 2	24 4

*Determined by digestion and distillation (Bremner[3])
**Soil moisture status 55% (soil with vegetation) and 48% (soil without vegetation) on oven dry basis after 2 h of irrigation

Table 2. Ammonia loss (mg ammonia/m^2 surface area basis) in sewage pond and sewage-irrigated soil with and without vegetation in 5-days measurement during summer '91

	Ammonia flux (mg/m^2 surface)	
Habitat	Per day*	In 5 days
Sewage pond water		
With vegetation (*Typha* and *Lemna*)	113^a (55)	564
Without vegetation	40^b (20)	201
Sewage-irrigated soil		
With vegetation (*L. vulgaris*)	57^b (25)	283
Without vegetation	89^a (41)	444

*Mean (standard deviation in parentheses) The means were tested by Students' *t* test Values followed by the same letter are not significantly different at 0 05 level

Table 1 reveals that the raw sewage before land application had more total N than ammonium-N and nitrate-N, showing thereby the presence of sizeable amount of nitrogen in organic form. The observations further revealed that the nitrogen fractions [total N and inorganic N (ammonium-N and nitrate-N)] of sewage pond under the vegetation zone were relatively higher than of those without vegetation, obviously due to the presence of rhizosphere and its ammonifying activity. Secondly, the nitrate-N was much less compared to ammonium-N irrespective of the aquatic site, suggesting low rates of nitrification due to the anaerobic nature of the system. These patterns were in contrast to sewage-irrigated terrestrial system where all the nitrogen fractions (except total N) in crop-sown soil were lower than in the soil without vegetation because of uptake of nitrogen by the crop. The nitrate-N concentration in soil was about three times higher than the ammonium-N due to active nitrification (aerobic process) in both the terrestrial sites (Table 1).

The results of field measurements of ammonia loss from the pond water and sewage-irrigated soil supporting vegetation and without vegetation are shown in Table 2. It was significantly higher (× 2.8) in pond water with macrophytes (*Typha* and *Lemna*) compared to the area without any macrophytes because of the higher flood water ammonium-N concentration in the former, resulting from the ammonifying activity of rhizosphere microorganisms. Higher ammonium-N results into more ammonia loss due to the direct relation of flood water ammonium-N concentration to ammonia losses[5,6].

The amount of ammonia loss and the nitrate N status in the soil without any crop was 1.5 times higher than the soil with crop. The latter site had faster rate of nitrification due to the rhizosphere effect, hence less level of steady state ammonium-N, unlike the former site (Table 1), thus leading to low N losses as ammonia (Table 2). Likewise because of no crop uptake, the amount of nitrate-N in soil without crop was higher (× 1.5) than the soil with crop (Table 1).

The study showed that a vegetated aquatic system provides a treatment avenue for the reduction of excess nitrogen contained in the domestic sewage through ammonia volatilization before it can be reutilized in land irrigation for plant growth.

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Occurrence of direct somatic embryogenesis on the sword leaf of *in vitro* plantlets of *Phoenix dactylifera* L. cultivar barhee

C. Sudhersan, M. M. AboEl-Nil* and A. Al-Baiz

Genetic Engineering Laboratory, Ministry of Agriculture and Water, P O Box 17285, Riyadh 11484, KSA
*Kuwait Institute for Scientific Research, P O Box 24885 Safat 13109, Kuwait

Date palm (*Phoenix dactylifera* L.) can be propagated clonally by somatic embryogenesis method. Success-